Jingxian Chen
1005354572

INF2178: Assignment4

Background and Introduction

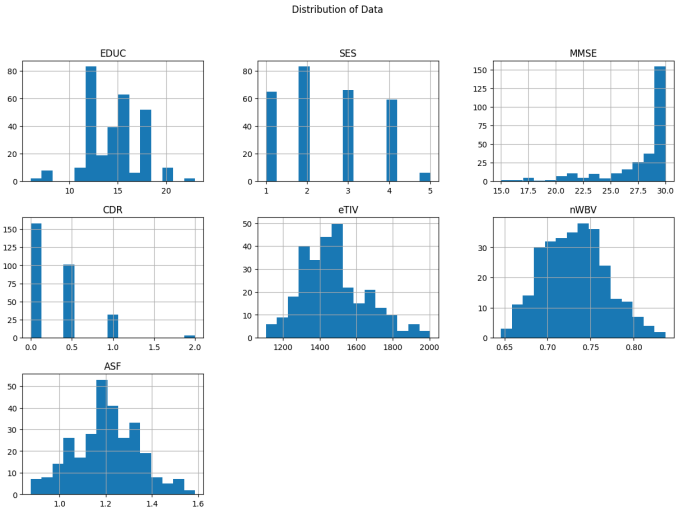
This report investigates the impact of Alzheimer's disease on brain morphology, focusing on the relationship between dementia status and normalized whole brain volume (nWBV) using the Open Access Series of Imaging Studies (OASIS) dataset. Employing mixed-ANOVA models, we analyze cross-sectional and longitudinal MRI data from subjects classified as nondemented and demented to discern patterns of brain volume changes across different age groups. This methodological approach allows for the adjustment for within-subject variability across multiple observations, providing insights into the progression of Alzheimer's disease and aiding in the refinement of diagnostic and therapeutic strategies.

Research Questions

1. How does the diagnosis of dementia (as indicated by the grouping into 'Demented' vs. 'Nondemented') affect the normalized whole brain volume (nWBV) in individuals, accounting for within-subject variability over multiple visits?

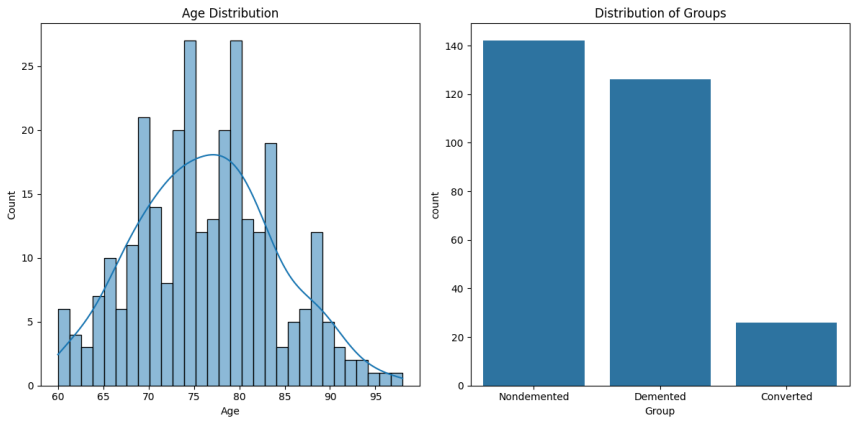
Exploratory Data Analysis

In this study, exploratory data analysis of various measures sheds light on the demographic and cognitive characteristics of the participants. Education and socioeconomic status display a bimodal and mid-to-high distribution pattern respectively, suggesting educational attainment that typically spans high school to undergraduate levels, though interpretation depends on the specific coding within the dataset. Cognitive assessments through MMSE scores reveal that the majority of participants likely maintain normal cognitive function, while CDR scores indicate that most do not exhibit or only display very mild signs of dementia. Brain volume measurements, such as eTIV, show a normal distribution, confirming the expected variability in brain size.



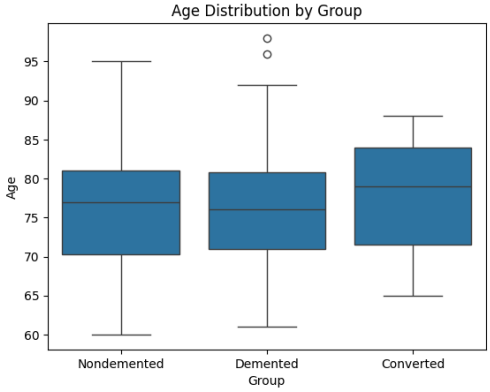
(Figure 1: Distribution of Data)

The histogram of Age Distribution overlaid with a density plot, shows a near-normal distribution skewed towards older ages, which is in line with the dataset's focus on older adults. The bar chart of Distribution of Groups displays a predominance of nondemented individuals, a smaller number of demented patients, and an even smaller group that has converted (likely from nondemented to demented over time).

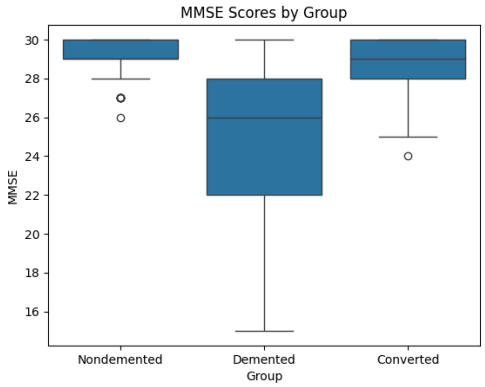


(Figure 2: Age Distribution and Distribution of Groups)

The boxplot of Age Distribution by Group across groups (Nondemented, Demented, and Converted) shows increasing median ages from nondemented to converted. This could suggest that conversion and dementia have a positive correlation with age. The boxplot of MMSE Scores by Group reveals a clear gradation in MMSE scores when comparing nondemented, demented, and converted groups. Nondemented individuals tend to have higher MMSE scores, indicative of better cognitive function, whereas converted and demented individuals display a wider range of lower scores, suggesting varying degrees of cognitive impairment.



(Figure 3: Age Distribution by Group)



(Figure 4: MMSE Scores by Group)

Results of Testing the Assumptions for Running Mixed Effects ANOVA

Mixed Effects ANOVA Results Interpretation

In analyzing the normalized whole brain volume (nWBV) using a two-way mixed-design ANOVA, we find a significant between-subjects effect of group status on brain volume (F(2, 141) = 6.712, p = 0.002), explaining

approximately 8.7% of the variance, indicating notable differences in nWBV among the dementia status groups. Moreover, the within-subjects effect of the visit is highly significant ($F(1, 141) = 94.251$, $p < 0.001$), accounting for a substantial 40.1% of the variance in nWBV, pointing to significant changes in brain volume over time. However, the lack of a significant interaction effect ($F(2, 141) = 1.534$, $p = 0.219$) suggests that these changes over visits are consistent across groups, implying a similar pattern of brain volume progression regardless of dementia status. The epsilon value of 1.000 for the visit indicates sphericity, affirming the reliability of the within-subjects effect. These results underscore the distinct impact of dementia status on brain volume and the consistent progression of brain changes over time across individuals.

Source	SS	DF1	DF2	MS	F	p-unc	np2	eps
Group_code	0.034	2	141	0.017	6.712	0.002	0.087	nan
Visit	0.007	1	141	0.007	94.251	0.000	0.401	1.000
Intercation	0.000	2	141	0.000	1.534	0.219	0.021	nan

(Table 1: ANOVA Result)

Assumption Analysis in Mixed Effects ANOVA

The results from the assumption checks conducted before the post-hoc tests provide important validations for the two-way mixed-design ANOVA performed on the dataset. Mauchly's test of sphericity yields a value of 1.0, indicating that the assumption of sphericity has been met for the within-subjects factor, which is 'Visit' in this context. Sphericity refers to the condition where the variances of the differences between all combinations of related groups (levels of the within-subjects factor) are equal. In essence, the variances of the repeated measures are equivalent, justifying the use of the parametric repeated measures ANOVA without adjustments to the degrees of freedom.

Furthermore, the normality test for the 'Visit' variable shows that the data for both visits adhere to the assumption of normality, with Shapiro-Wilk test values close to 1 ($W = 0.990075$ for Visit 1 and $W = 0.989654$ for Visit 2) and p-values (0.372060 and 0.366703, respectively) well above the conventional alpha level of 0.05. This suggests that the nWBV measurements are normally distributed at each visit, satisfying another crucial assumption for conducting ANOVA.

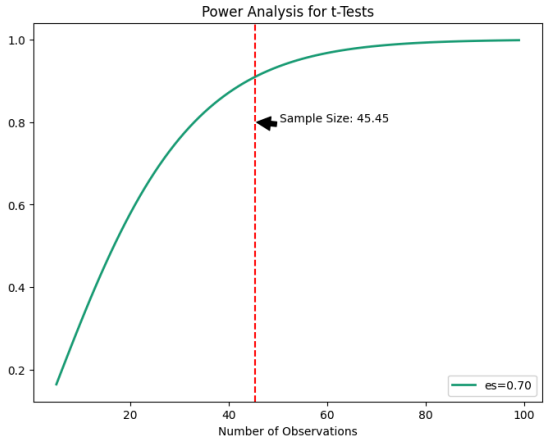
Post-hoc Test

The post-hoc test results indicate significant differences in normalized whole brain volume (nWBV) across multiple comparisons. Firstly, the change in nWBV between the first and second visits is significant ($p < 0.001$), suggesting a strong time effect. When examining group differences, the post-hoc analysis reveals a significant difference in nWBV between the 'Converted' and 'Demented' groups ($p < 0.001$), and between the 'Demented' and 'Nondemented' groups ($p < 0.001$), while the difference between 'Converted' and 'Nondemented' groups is not statistically significant. The interaction effects between visits and group comparisons show significance in some, notably between 'Converted' at visit 1 and 'Demented' at visit 1 ($p = 0.001$), and 'Converted' at visit 2 and 'Demented' at visit 2 ($p < 0.001$). These results emphasize the complexity of brain volume changes,

highlighting both temporal changes and the variability associated with different stages of dementia progression.

Statistical Power Analysis Plot for T-tests

The power analysis depicted in the graph illustrates the relationship between sample size and the power of a t-test, given a large effect size (d = 0.7), a significance level of 0.05, and a desired power of 0.91. The analysis determines that a sample size of approximately 45.45 participants is required to achieve the desired power, ensuring a high probability of detecting an effect of this magnitude, should it exist. The curve on the graph shows an increasing power with a rising number of observations, and the vertical dashed line indicates the point where the desired power is attained for the given effect size. This power analysis is critical for designing future experiments to ensure they are adequately powered to detect clinically or scientifically significant effects.



(Figure 5: Power Analysis Plot for t-Test)

Conclusion

In summary, our study addressed how dementia diagnosis impacts brain volume by comparing 'Demented' and 'Nondemented' groups. Significant differences in normalized whole brain volume (nWBV) were found across these groups, with brain volume consistently decreasing over time, regardless of dementia status. Assumptions were validated, ensuring the reliability of our ANOVA results, and power analysis confirmed that a sample size of approximately 45 is adequate for detecting true effects in similar future studies. These findings enhance our understanding of dementia's progression and provide a solid foundation for ongoing research into neurodegenerative diseases.